

GEOHERMAL RESOURCES AT NPR-3



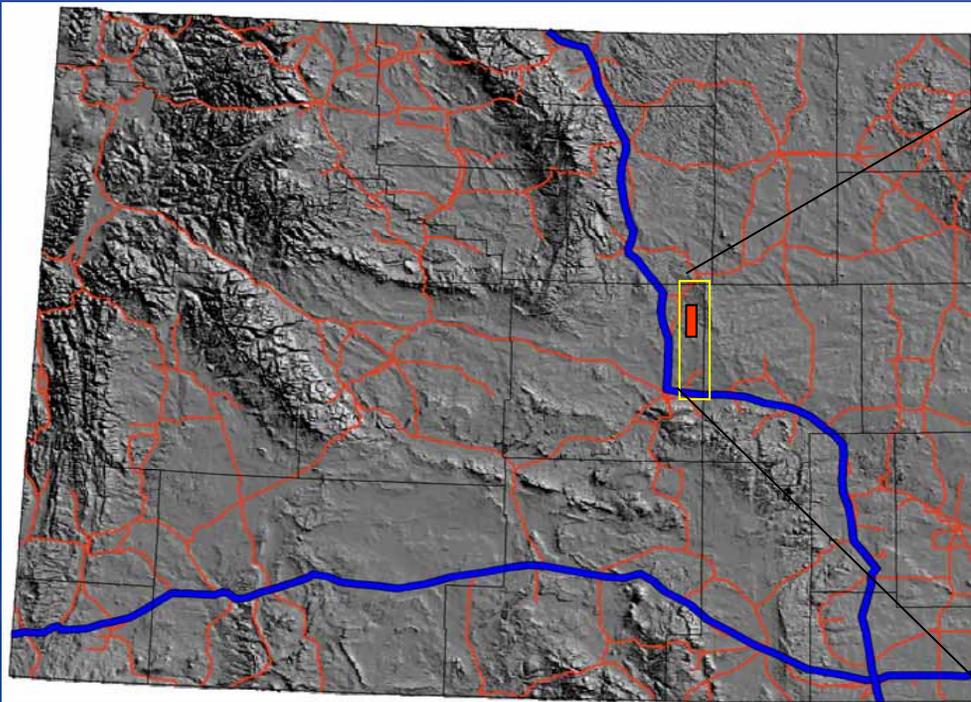
Mark Milliken

March 2006



The Naval Petroleum Reserves





NPR-3 LOCATION



NPR-3

Salt Creek Anticline Trend

WHY CONSIDER GEOTHERMAL ASSETS IN A STRIPPER OIL FIELD?

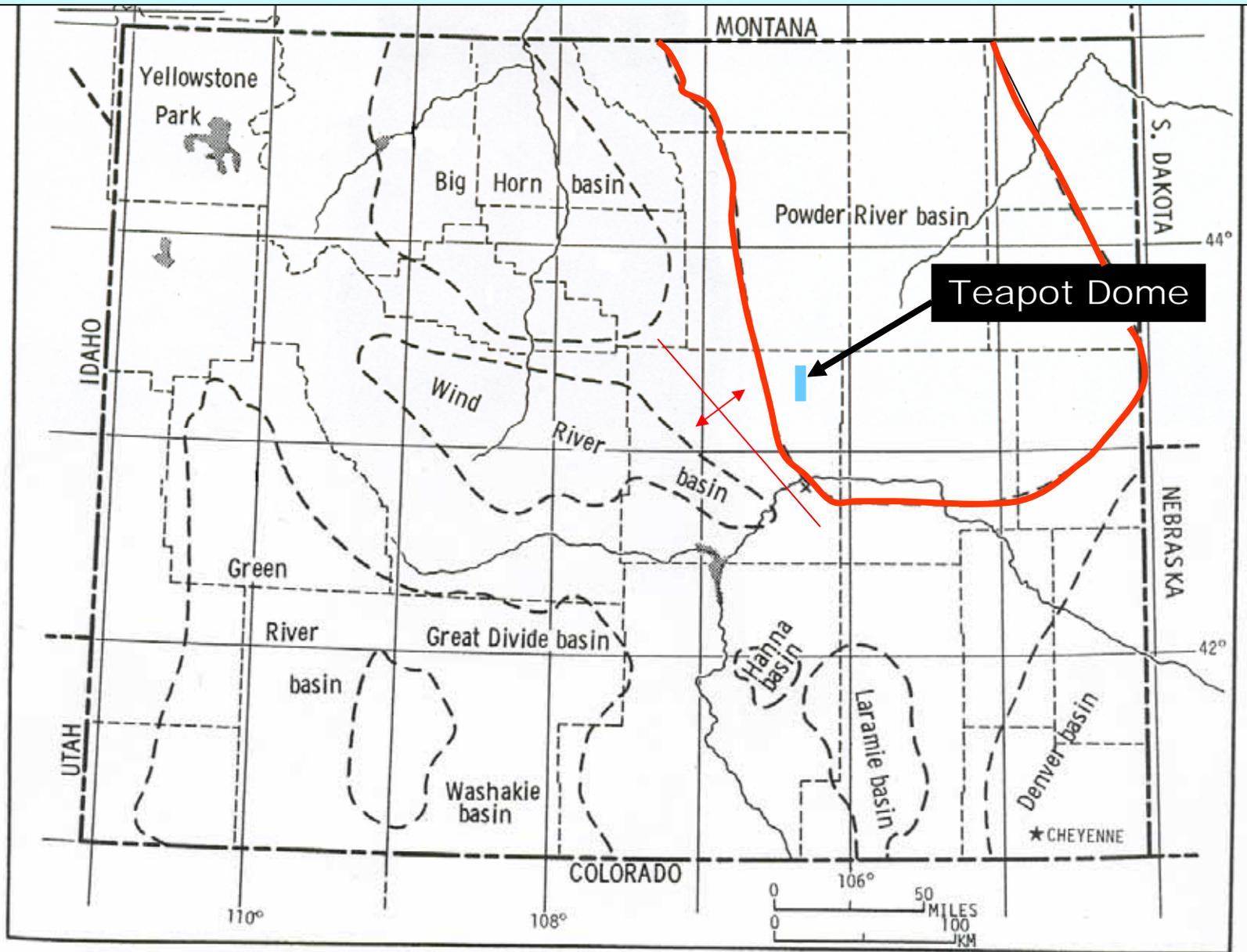
RMOTC will partner with industry and academia to provide a test site for technologies that to reduce energy-related operational costs.

- **Energy efficiency**
- **Energy conservation**
- **Alternative energy sources**

KEY CHALLENGES

- **Acceptance by Industry**
- **Creation of a Joint Industry Partnership (JIP)**
- **Consensus on best technologies**
- **Funding for infrastructure support**
- **Funding of Projects**

Wyoming Depositional Basin Settings



NPR-3 STRATIGRAPHY

DEPTH

1000

2000

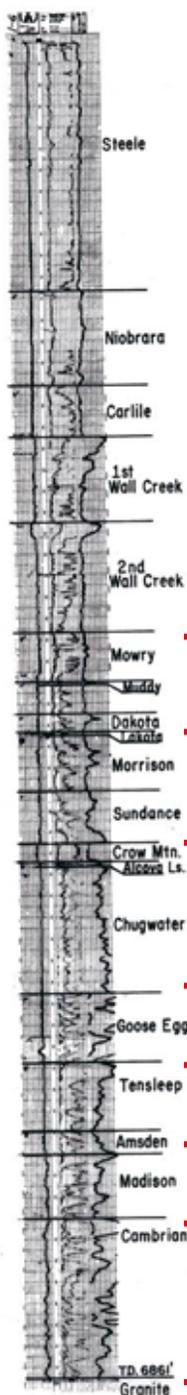
3000

4000

5000

6000

7000



WELL 1-G-10, 1952

UPPER CRETACEOUS

LOWER CRETACEOUS

JURASSIC

TRIASSIC CHUGWATER

PERMIAN GOOSE EGG

PENNSYLVANIAN TENSLEEP

MISSISSIPPIAN MADISON LS

CAMBRIAN SS

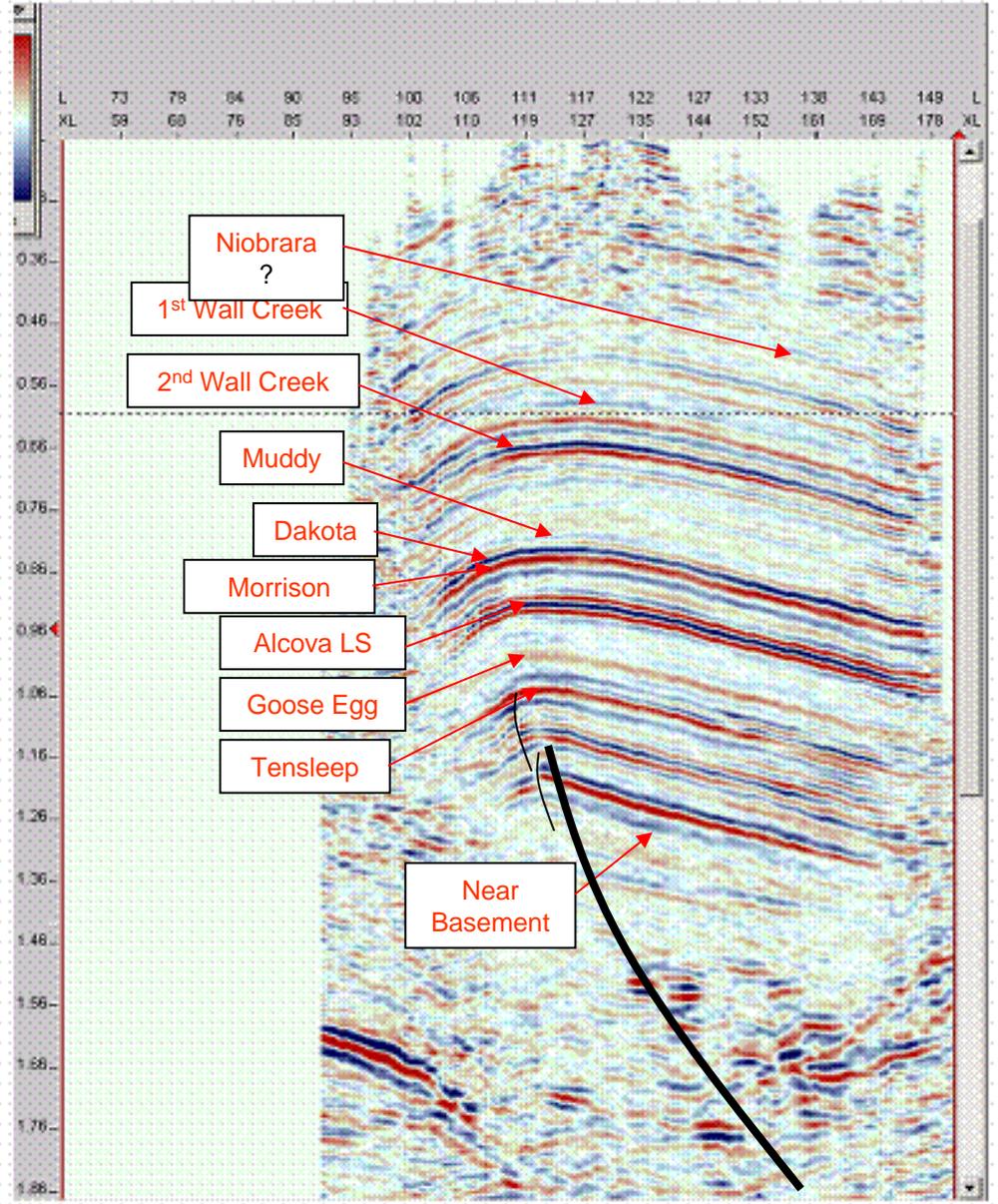
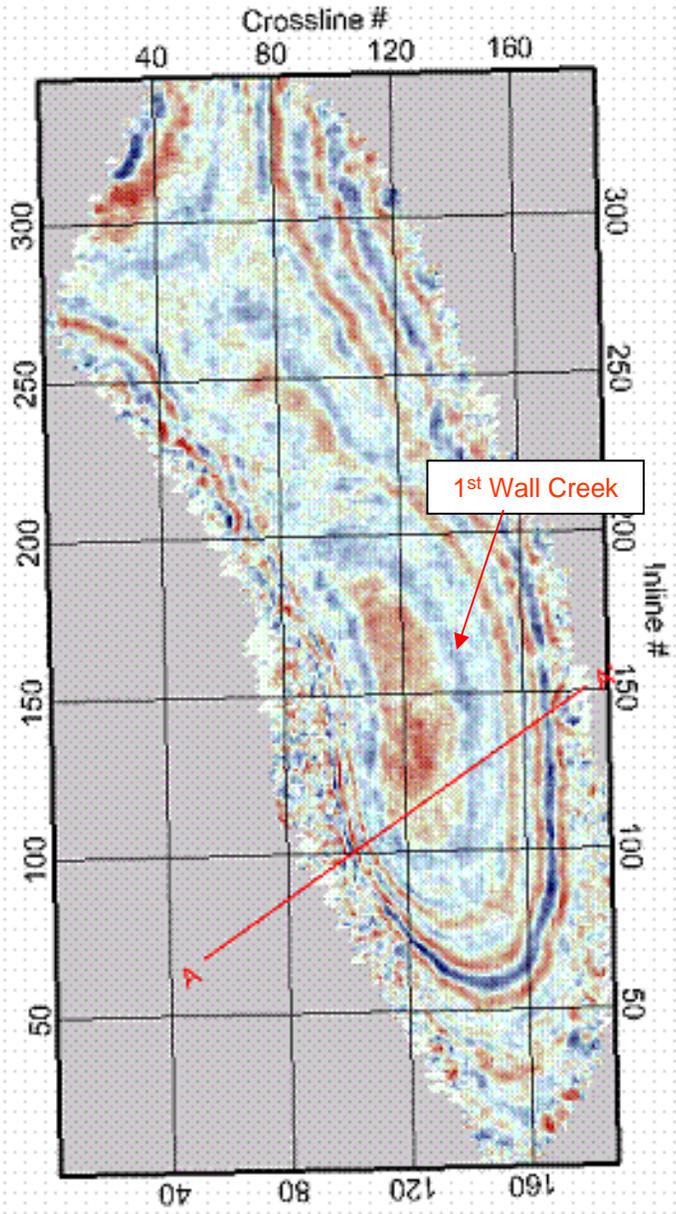
PRECAMBRIAN BASEMENT



Rocky Mountain
Oilfield Services



NPR-3 SEISMIC



NPR-3 STRATIGRAPHY

DEPTH

1000

2000

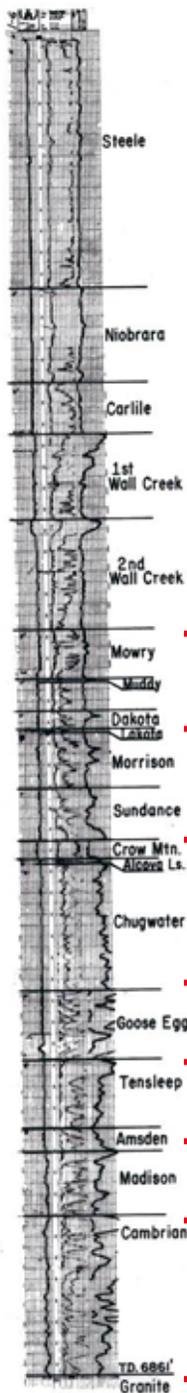
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CAMBRIAN SS

PRECAMBRIAN BASEMENT



Rocky Mountain



Fractured Precambrian Granite



NPR-3 STRATIGRAPHY

DEPTH

1000

2000

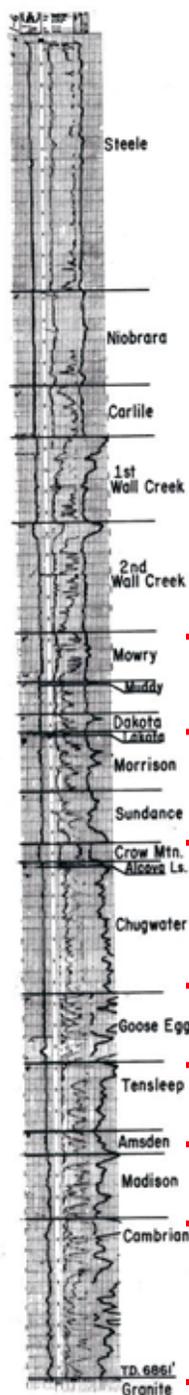
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PRECAMBRIAN BASEMENT



Rocky Mountain
Oilfield Services



Fractured Cambrian Sandstone



NPR-3 STRATIGRAPHY

DEPTH

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2000

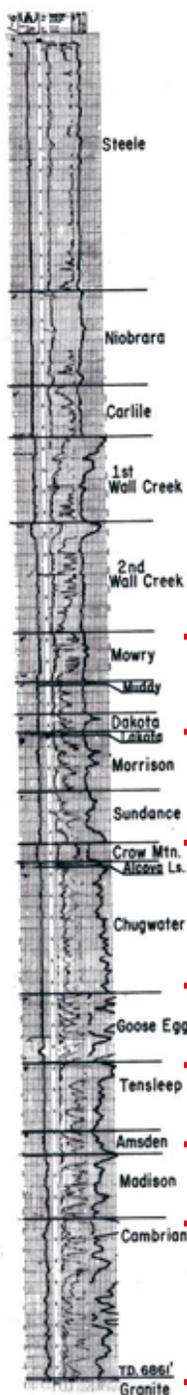
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Rocky Mountain



Fractured Madison Limestone



NPR-3 STRATIGRAPHY

DEPTH

1000

2000

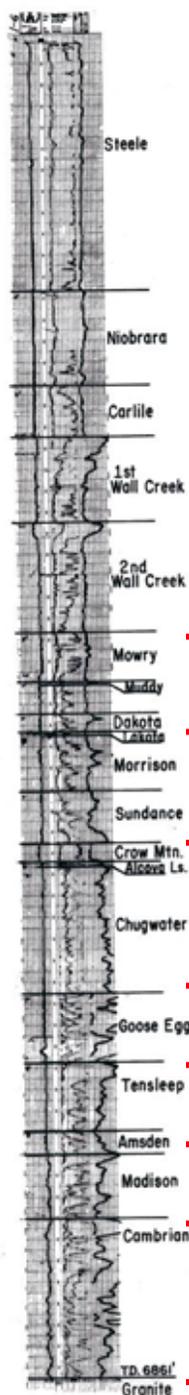
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PRECAMBRIAN BASEMENT



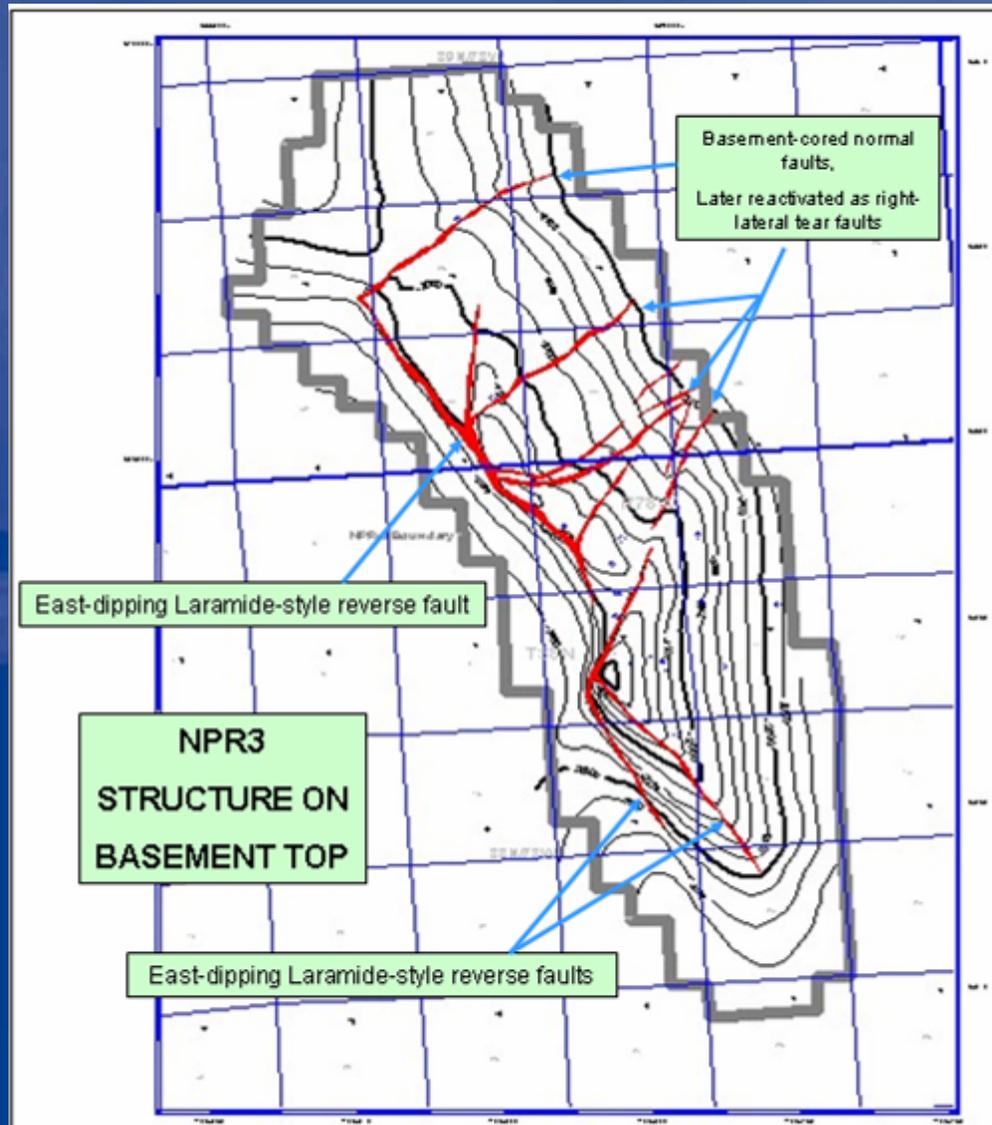
Rocky Mountain
Oilfield Services



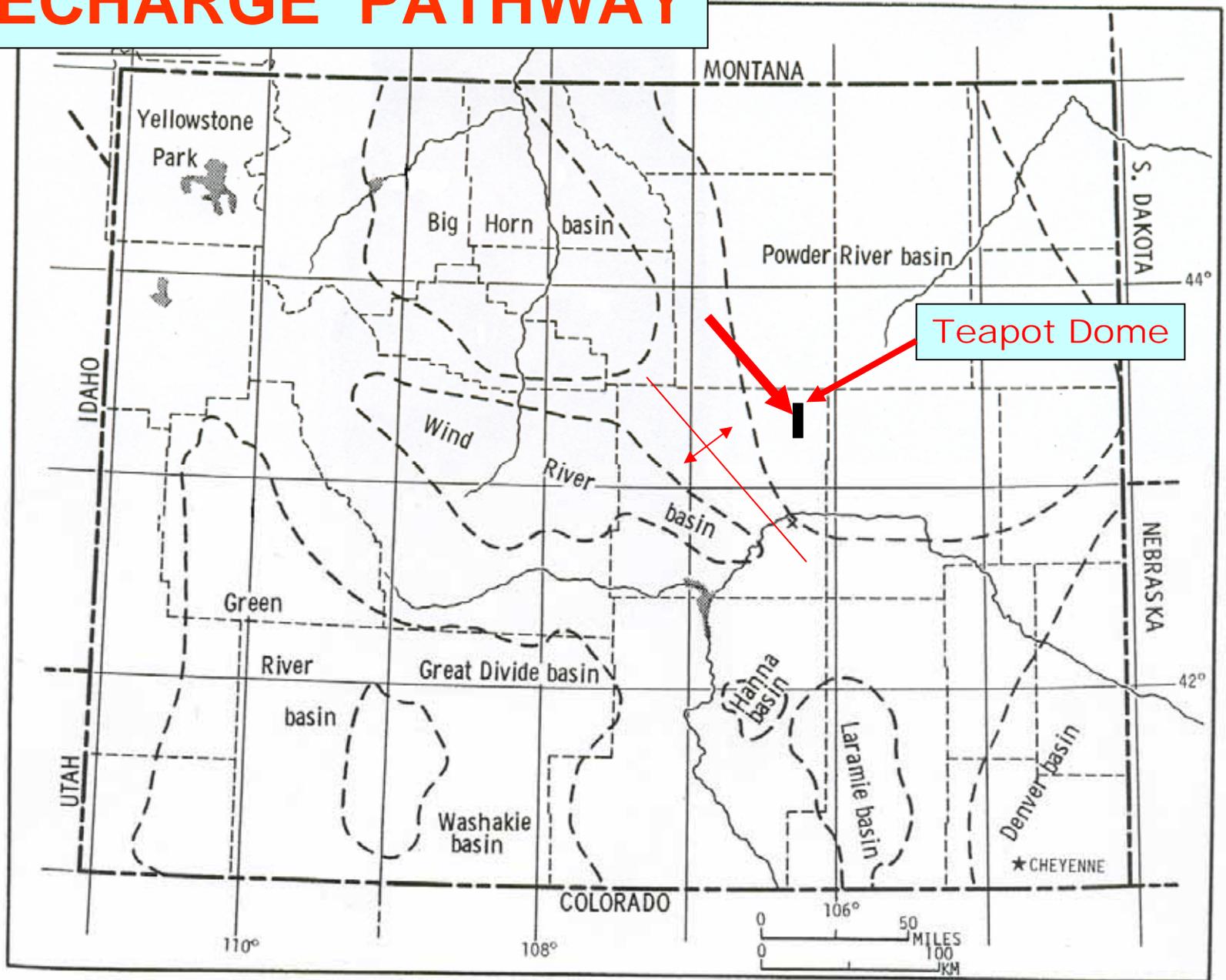
Pennsylvanian Tensleep Sandstone



BASEMENT STRUCTURE



RECHARGE PATHWAY



NPR-3 RECHARGE SYSTEM

BIG HORN RANGE

± 90 MILES

APPROXIMATE TOPOGRAPHIC SURFACE

NPR-3

RECHARGE

MADISON LIMESTONE

Fractures

Basement

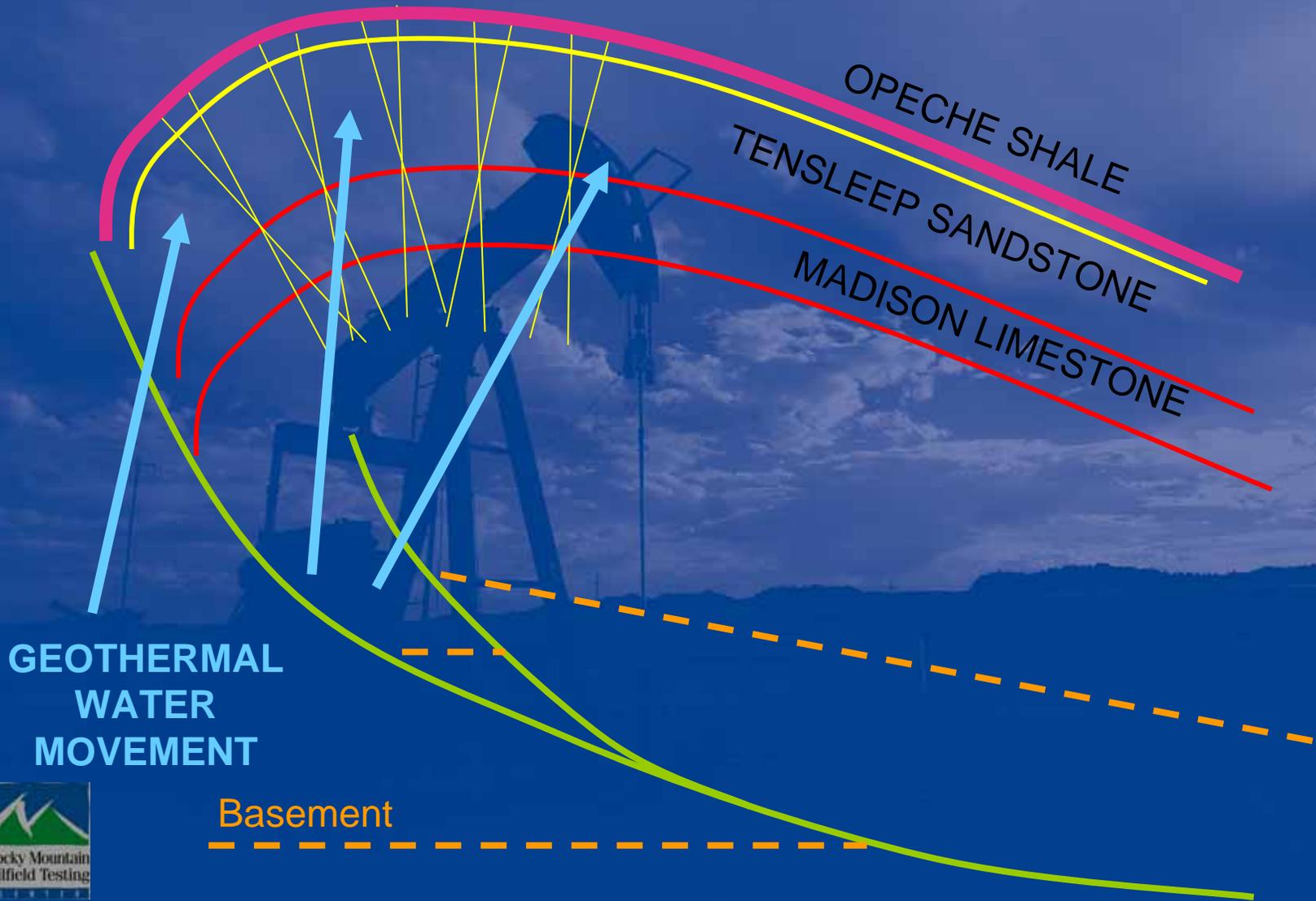
Reverse faults

NW

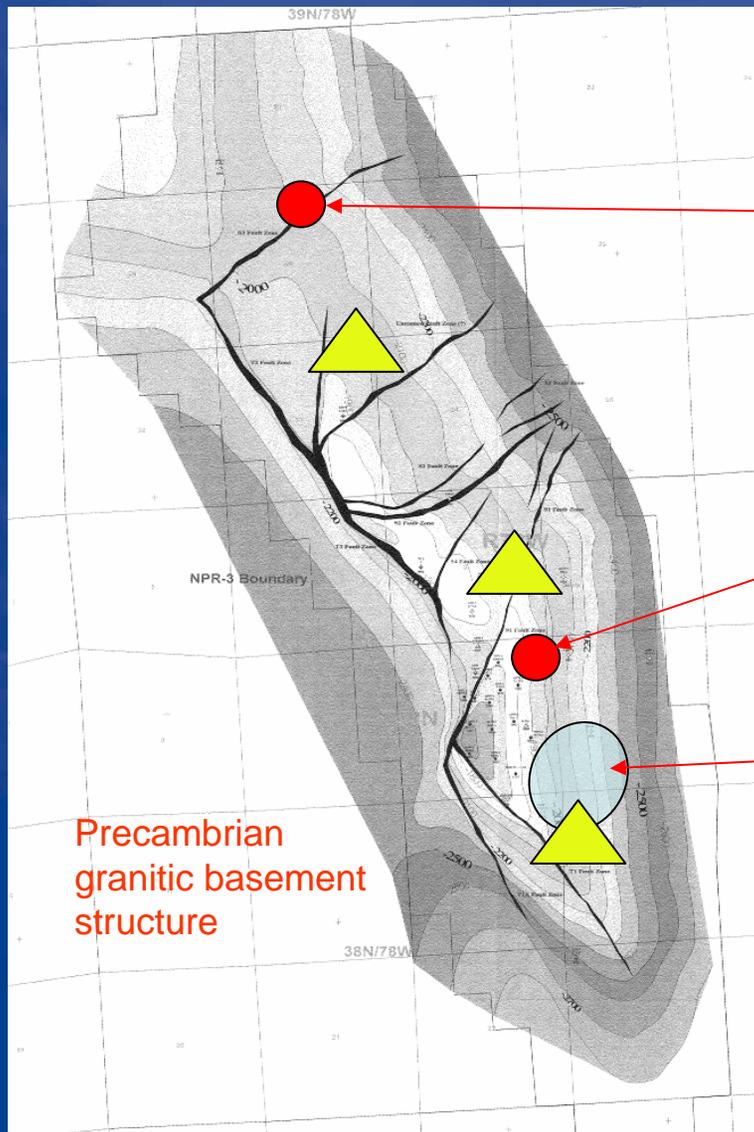
SE



NPR-3 MADISON AQUIFER



POSSIBLE GEOTHERMAL SUPPLY WELL LOCATIONS



17-WX-21
Madison and Tensleep
Possibly 35 MBWPD flowing

57-WX-3
Madison and Tensleep
Possibly 10 MBWPD flowing

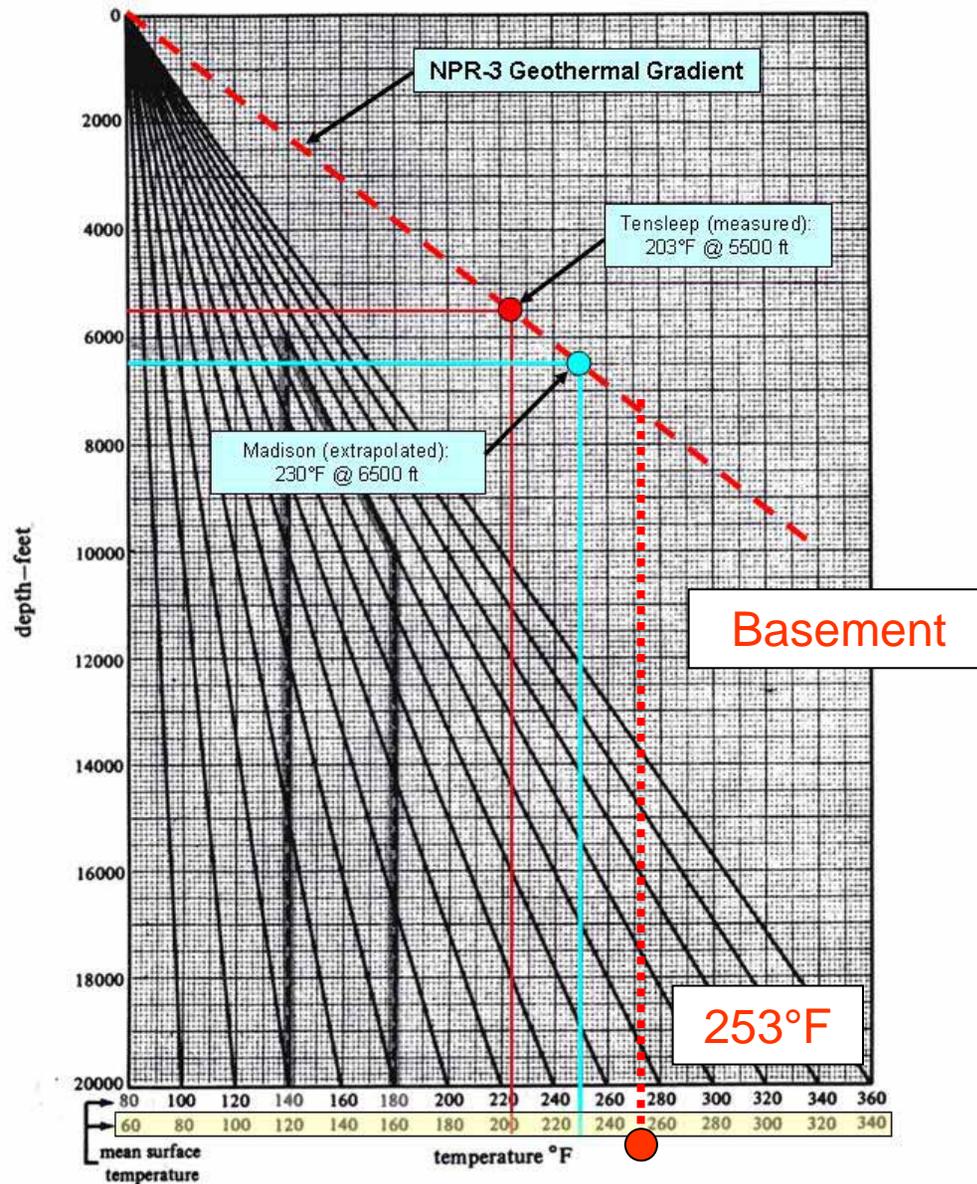
TENSLEEP PRODUCING AREA

OTHER POSSIBLE TENSLEEP
SOURCE WELLS AND
DEEPENING CANDIDATES

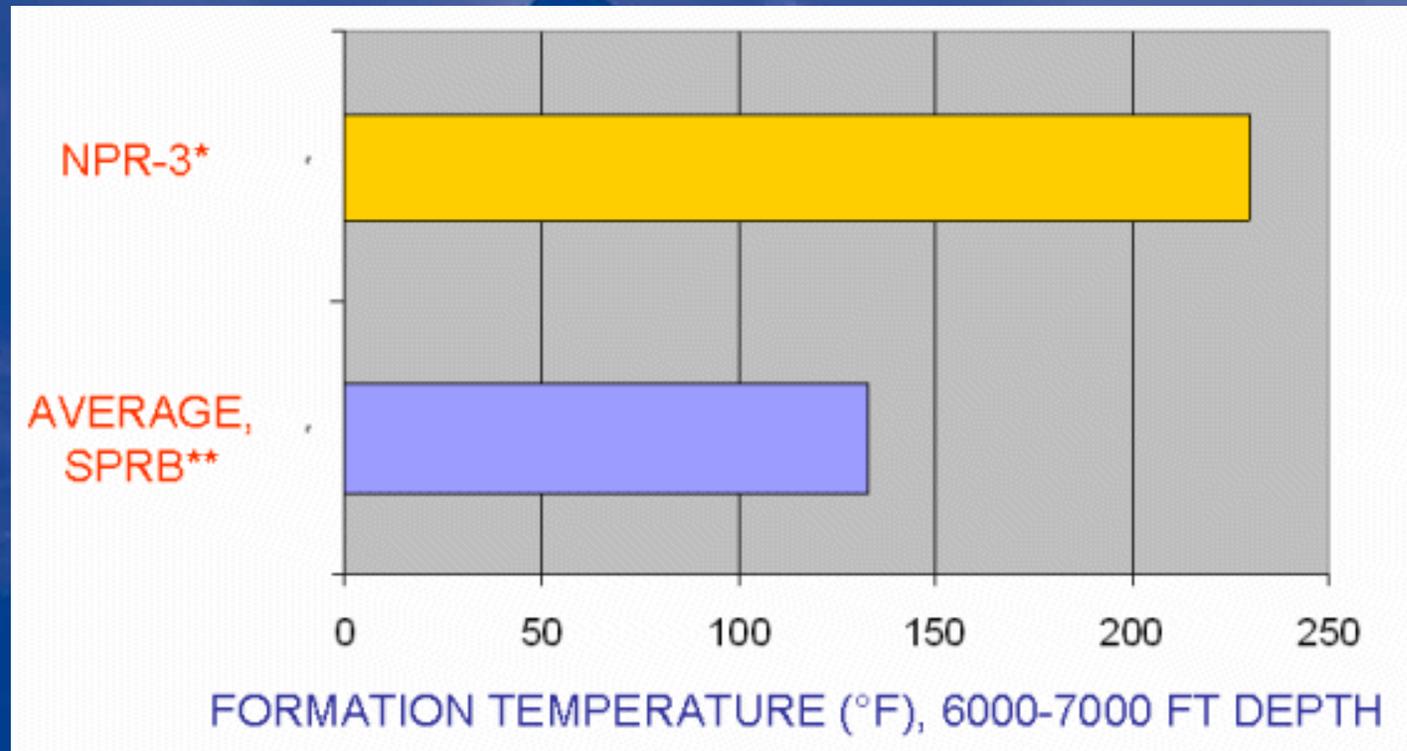


ESTIMATION OF MADISON FORMATION TEMPERATURE

Mark Milliken 1/27/06



GEOHERMAL TEMPERATURE COMPARISON SOUTHERN POWDER RIVER BASIN

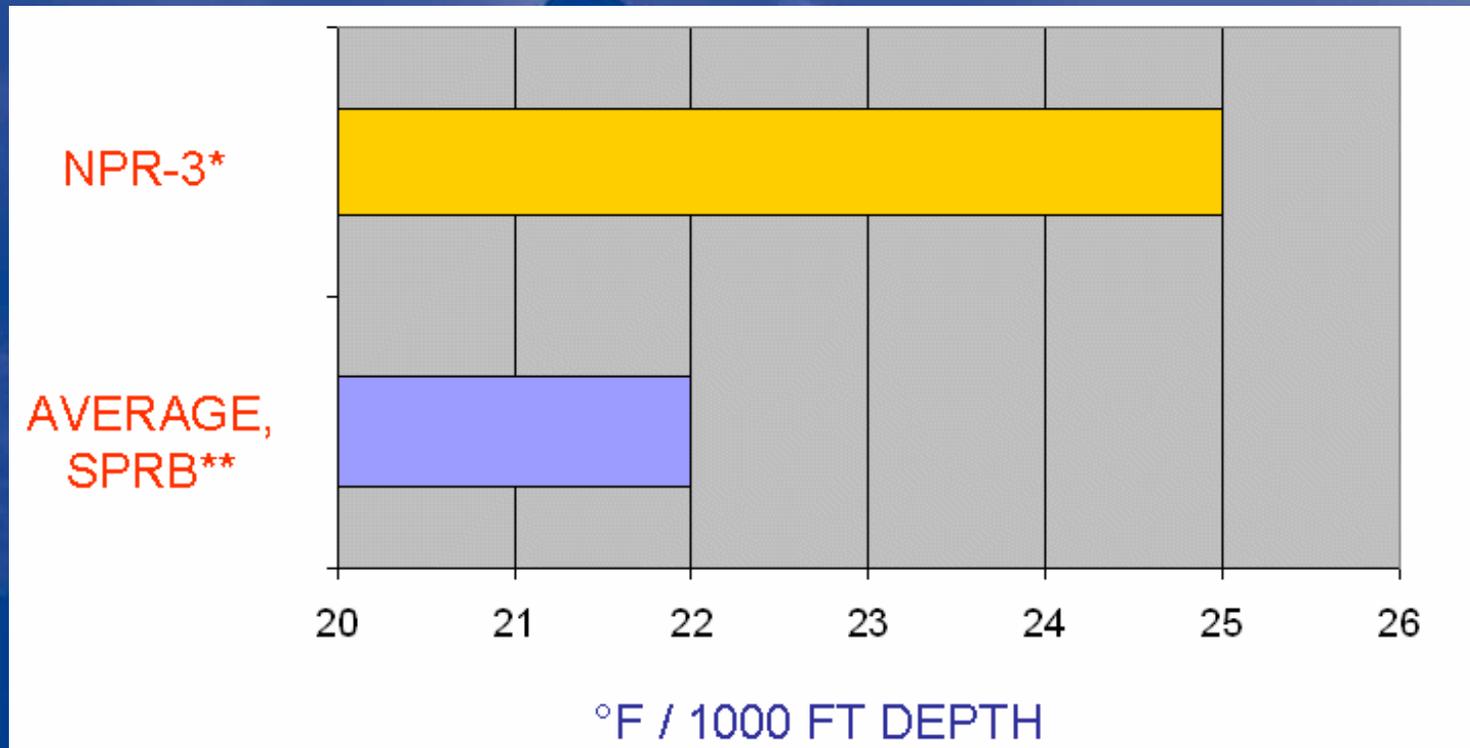


*Projected from Tensleep data

**WGS data, 1986



GEOHERMAL GRADIENT COMPARISON SOUTHERN POWDER RIVER BASIN



*Projected from Tensleep data

**WGS data, 1986



MADISON WATER QUALITY

17-WX-21

DISSOLVED SOLIDS

RESULTS AS COMPOUNDS

	mg/l	meq/l		mg/l
Cations				
Sodium, Na (Calc.)	1,758	76.44	as NaCl	
Calcium, Ca	316	15.80	as CaCO ₃	790
Magnesium, Mg	51	4.20	as CaCO ₃	210
Barium, Ba	0	0	as BaSO ₄	0
Cations Total	2,125	96.44		
Anions				
Chloride, Cl	1,032	29.10	as NaCl	1,700
Sulfate, SO ₄	1,352	28.12	as Na ₂ SO ₄	2,000
Carbonate, CO ₃	0	0	as CaCO ₃	0
Bicarbonate, HCO ₃	2,391	39.22	as CaCO ₃	1,960
Anions Total	4,775	96.44		
Total Dissolved Solids (Calc.)	6,900			
Total Iron, Fe	19.5		as Fe	19.5
Acidity to Phenolphthalein, CO ₂	145		as CaCO ₃	330
Dissolved Oxygen	0.1			
Sulfide, as H ₂ S	12.5			



POTENTIAL WATER PRODUCTION RATES

POTENTIAL NEW WATER PRODUCTION

WELL	ZONE	RATE MBWPD		COMMENTS
		LOW	HIGH	
17-WX-21	MADISON	20	25	FLOWING
17-WX-21	TENSLEEP	4	10	FLOWING, MUST BE PERFORATED
41-2-X-3	TENSLEEP	1	3	FLOWING, TIGHT FORMATION
41-2-X-3	MADISON	6	12	FLOWING, NEEDS DEEPENING
48-X-28	TENSLEEP	2	6	FLOWING, TOO SMALL TO DEEPEN
61-2-X-15	MADISON	6	12	FLOWING, NEEDS DEEPENING
61-2-X-15	TENSLEEP	2	6	FLOWING, NEEDS CASING, CURRENTLY PLUGGED
57-WX-3	MADISON	2	6	FLOWING, REQUIRES ACIDIZATION
TOTAL NEW FLOWING PRODUCTION		43	80	
TOTAL NEW PUMPING PRODUCTION		86	160	
ALL OTHER	TENSLEEP	40	50	PUT ALL CURRENT WELLS ON PUMP
TOTAL POTENTIAL WATER		126	210	

NPR-3 GEOTHERMAL HEAT POTENTIAL

Assumptions

1. 130 MBWPD
2. 220° F surface temperature of water
3. 48° Mean ambient temperature (WGS data)
4. 53 MBTU/°F - BWPD

Heat content

$$\begin{aligned} \text{Total heat content} &= (53,000)(220 - 48) \times 130,000 \\ &= \mathbf{1.18 \times 10^{12} \text{ BTUs per day}} \end{aligned}$$

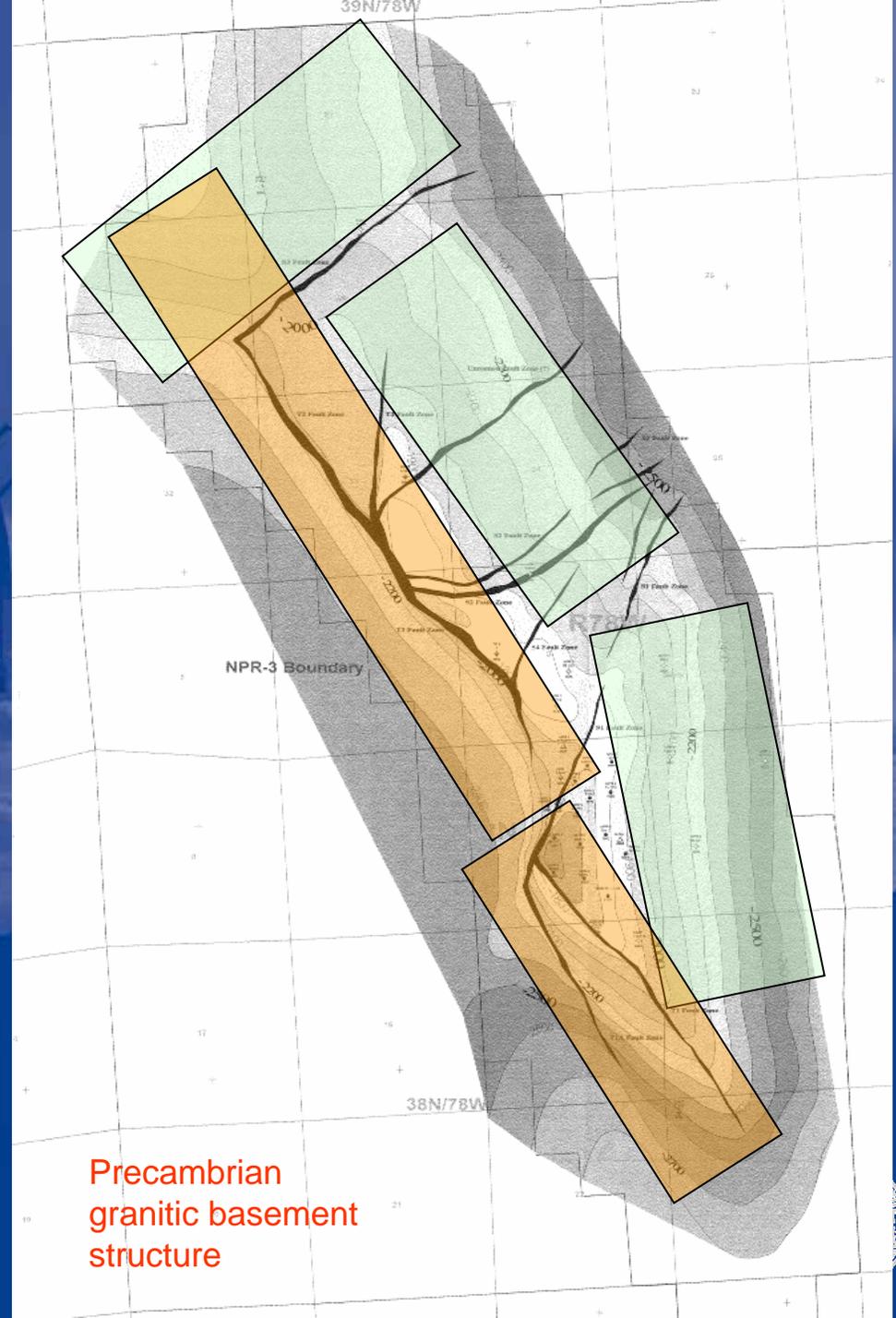
Power potential

1 MW can be extracted from 1.7 MBWPD at 200° F (SMU data)
For 130 MBWPD, power = $130/1.7 = \mathbf{76 \text{ MW}}$

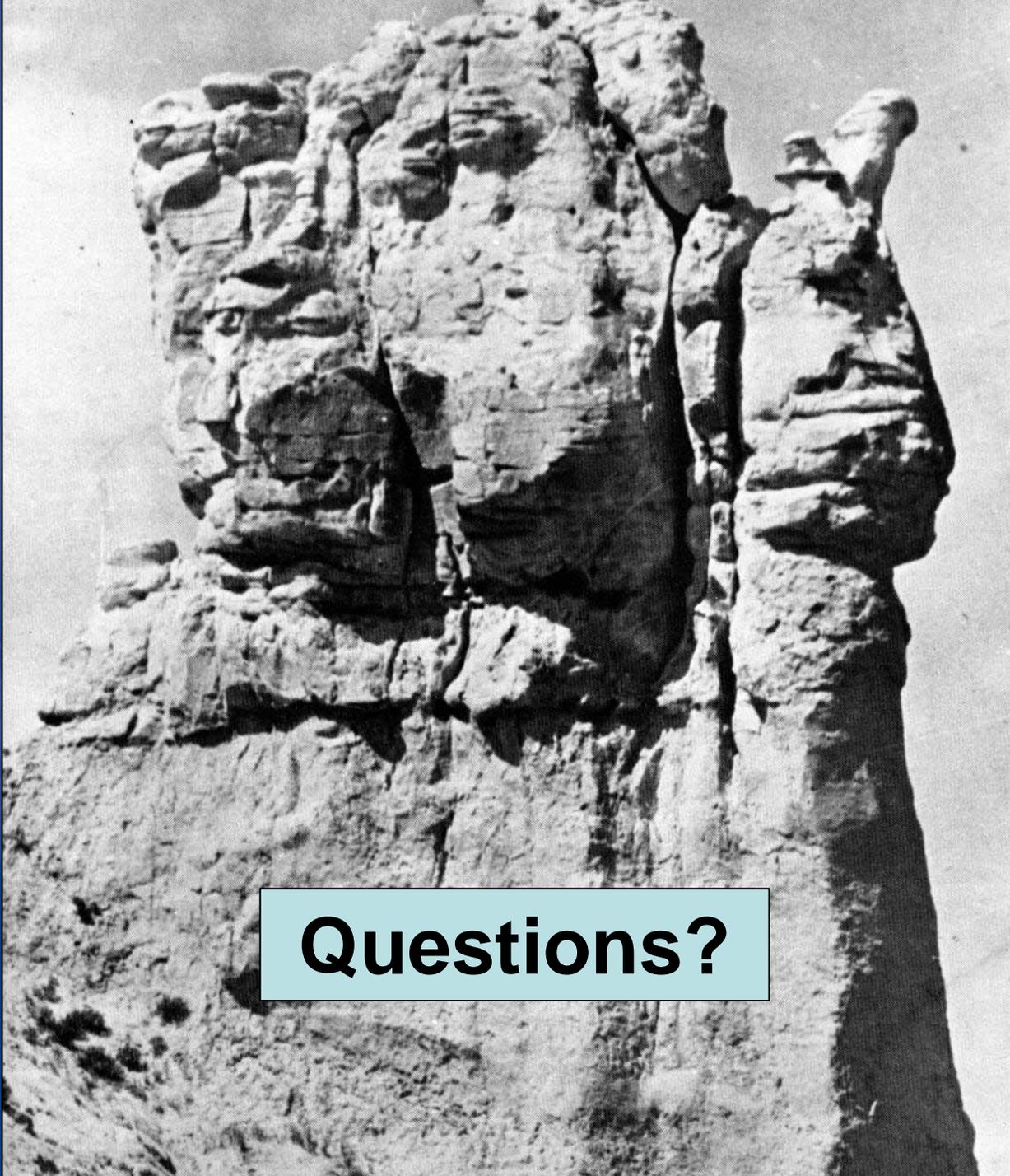
POSSIBLE FUTURE GEOTHERMAL DEVELOPMENT AREAS

Madison – Tensleep potential

Fractured basement potential



Precambrian
granitic basement
structure



Questions?